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EXPERIMENTAL ANALYSIS OF DOMESTIC REFRIGERATOR WITH SUB-COOLING AND DIFFUSER AT CONDENSER INLET BY USING R290/134a REFRIGERANT WITH TiO2 NANO PARTICLES

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Abstract: *Now a days refrigeration systems have shown many applications in both industrial and domestic Sectors. The majority of domestic refrigerators works on vapour compression system. Vapour compression system uses expansion valve to reduce the pressure of liquid refrigerant and delivers to the evaporator. The leakages of widely used hydro fluoro carbon refrigerants from refrigerator shows severe impact on the environment like global warming, ozone depletion, etc. In order to overcome this problem a mixture of nano particles with Blend refrigerants combing hydrofluorocarbons and hydrocarbons are used in this experiment. .Blend refrigerants combing hydrofluorocarbons and hydrocarbons are good substitute to reduce global warming potential. By adding Nano particles it can increase cooling capacity of the system and reduces compressor work. In the present work diffuser is incorporated at the inlet of condenser, and heat exchanger is arranged at outlet of condenser. Diffuser provides additional compression to the refrigerant and reduces mechanical work for the compressor. Heat exchanger increases Refrigeration effect.*

Index Terms *– **passive devices (diffuser & sub-cooling), R290/R134a blended refrigerants. TiO2 nano particles***

I. INTRODUCTION

Most of the domestic sector refrigerators work on vapour compression refrigeration system. The leakages of refrigerants from refrigerator shows a severe impact on the environment like global warming, ozone depletion, etc. In order to overcome these problems, the HC & HFC Mixtures of R290/R134a is used. This refrigerant has zero ODP and negligible GWP (0-3). Hydro carbon is an Eco-Friendly Refrigerant which is available at Low Cost can be used as an alternative to HFCs like R134a. For a refrigeration system, the coefficient of performance can be enhanced either by the reduction of compressor input work or by increasing the refrigeration effect. Compressor input work can be reduced with the installation of the diffuser at the inlet of the condenser section. The diffuser converts the kinetic energy of a vapour refrigerant leaving compressor into pressure energy, which leads to a reduction of work input to the compressor. Apart from this, the diffuser may reduces the vibrations that are occurred at the heat rejection section (condenser) due to refrigerant's high velocity at the compressor outlet. Also, refrigeration effect can be increases with the installation of the sub-cooling at outlet of condenser.

II. INTRODUCTION TO NANO FLUIDS

Fluids have poor heat transfer properties as compared with most solids which is the primary hindrance of high compactness and the effectiveness of the heat exchanger. An innovative way of improving the thermal conductivities of common fluids is to suspend small solid particles in the fluids. These suspended solid particles are at high thermal conductivities several hundreds of times greater than all of the conventional fluids combined. To form slurries from particle of various types like metallic, non-metallic and polymeric are added into these fluids. In the various industrial fields for improvements thermal conductivity and suspension stability both are required. A new class of fluid to motivate these two leads to development of nanofluids. A new kind of fluid is a Nanofluid which consists of uniformly dispersed and suspended nanometer-sized particles or fibers in fluids and has unprecedented thermal characteristics. Nano-powders have a combination of small particles size, narrow size distribution and high surface area to volume ratio. The physical and chemical properties of these nanoparticles often deviate from their bulk materials when the particle size decreases to a specific regime. The nanoparticles materials used in nanofluids are oxide ceramics (TiO2, Al2O3, CuO), nitride ceramics (AIN, SiN), carbide ceramics (SiC, TiC), metals (Ag, Au, Cu, Fe), semiconductors (TiO2), single or double or multi walled carbon nanotubes (SWCNT, DWCNT, MWCNT), and composite materials such as nanoparticles core polymer shell composites. These materials can be utilized to develop stable suspensions with enhanced flow, heat-transfer and other characteristics

Table1: Properties of Titanium dioxide (TiO_2):

Particle size	<25nm
specific surface area	200-220m^2/g
Density	3.94g/cc at 25ºC
Bulk density	0.04-0.06g/cc
Melting point	1825ºC

III. EXPERIMENTAL SETUP & METHODOLOGY

In the present study the refrigerant selected is blended R290/R134a.Propane (R290) is more widely adopted in domestic Refrigerator, because of its better environmental and energy performances. A new refrigerator test system was built up according to the requirement of this study. R290/R134a is used as refrigerant in 160L capacity refrigerator. A diffuser is attached at condenser inlet to convert kinetic energy available at condenser inlet to pressure energy which gives additional compression, sub-cooling is attached at condenser outlet to increase refrigeration effect and TiO2 Nano particles are added to the lubricant to reduce compressor work and to increase cooling capacity of system

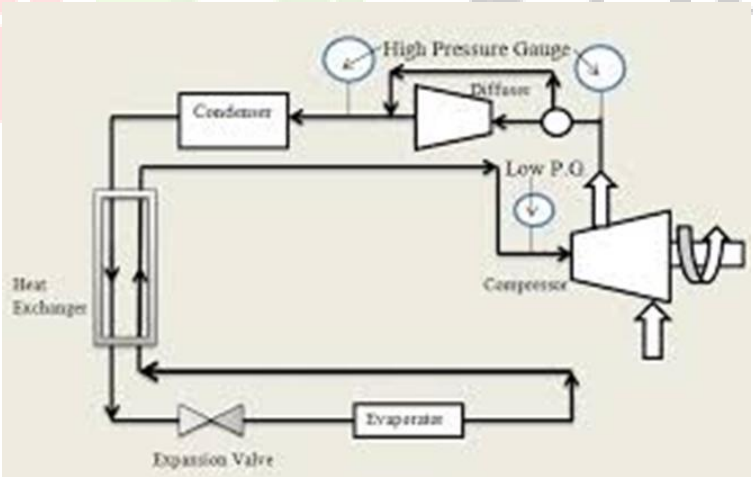


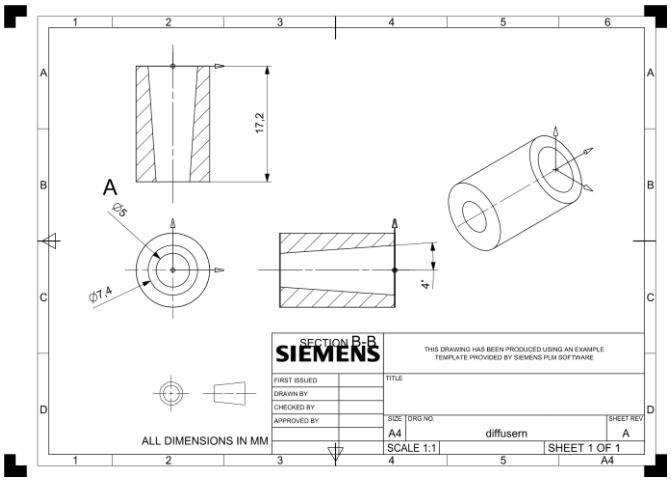
Fig 1: Proposed Refrigeration system

IV.MANUFACTURE AND FABRICATION OF DIFFUSER:

The was designed and manufactured based on the following standard equation

Proposed diagram

Line diagram of diffuser



Where D_1 is the inlet diameter of the diffuser = 5 mm

D_2 is the outlet diameter of the diffuser = 7.4 mm

L is the length of the diffuser = 17.16 mm

Ø is the angle of divergence = 4°

$$\text{Tan } ø = \frac{(\textit{Exit diameter} - \textit{inlet diametr})}{2X \textit{ Length of diffuser}}$$

V. REFRIGERANT AND EXPERIMENTAL PROCEDURE

HC (Hydrocarbon) mixture can be used as an alternative refrigerant to HFC refrigerants as there is no fluorine element. A hydrocarbon (HC) includes naturally occurring substances like isobutane and propane. In many ways, Hydrocarbons has better properties like better efficiency, transport, energy Efficiency, heat transfer properties, and environmentally sound but the major concern is HC's are flammable in nature. About 35% of refrigerators in northern Europe are based on hydrocarbons. First R290 compressor is fixed and then nitrogen gas is filled in the compressor and then leak detection test (soap bubble test) conducted and conformed that there are no leakages in the system. Then vacuum is created by another compressor and then R290 refrigerant charged into the compressor. Temperature and pressure readings are noted by using thermocouples and pressure gauges respectively at required places for normal cycle. After noted the readings R290 refrigerant is discharged from the compressor and vacuum is created by using vacuum pump. Then R290/R134a blended refrigerant by mass charge 30g+50g is charged in to the R290 compressor. Temperature and pressure readings are noted by using thermocouples and pressure gauges respectively at required places for normal cycle. Then diffuser valves and sub-cooling valves are opened and Temperature and pressure readings are noted by using thermocouples and pressure gauges. Then nano lubricant is prepared with the concentration of 0.18g/300ml. and Temperature and pressure readings are noted by using thermocouples and pressure gauges

VI. PERFORMANCE PARAMETER CALCULATION:

Net Refrigeration Effect (NRE) = h_1-h_4 kj/kg

Work of compression (Wc) = h_2-h_1 kj/kg

Diffuser work (W_d) = h_d-h_2 kj/kg

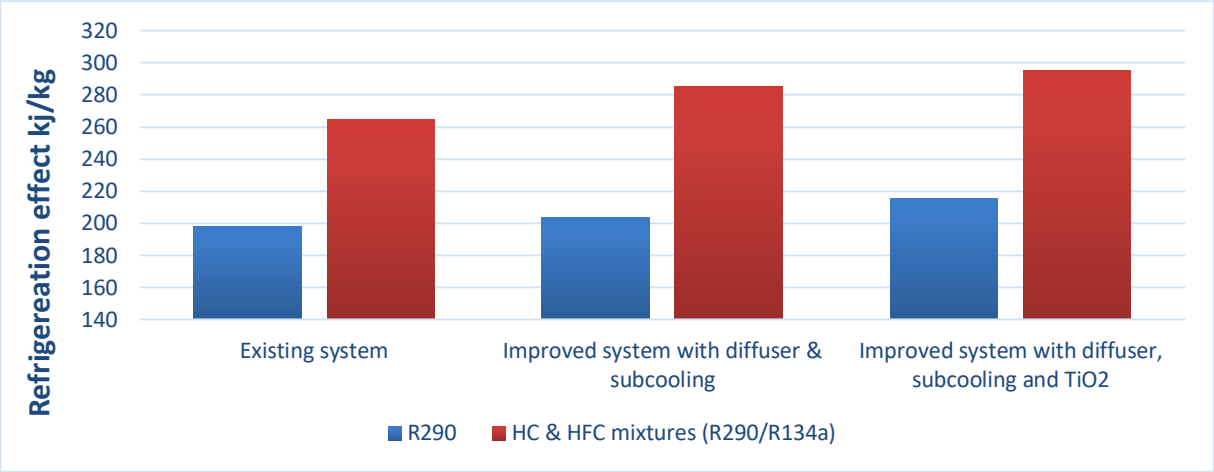
Reduction in Compressor Work (W) = Wc-Wd kj/kg

Coefficient of Performance (COP) = NRE / W

The values of enthalpies h_1, h_2, h_d, h_3, h_4 are taking from p-h chart

VII. RESULTS AND DISCUSSION:

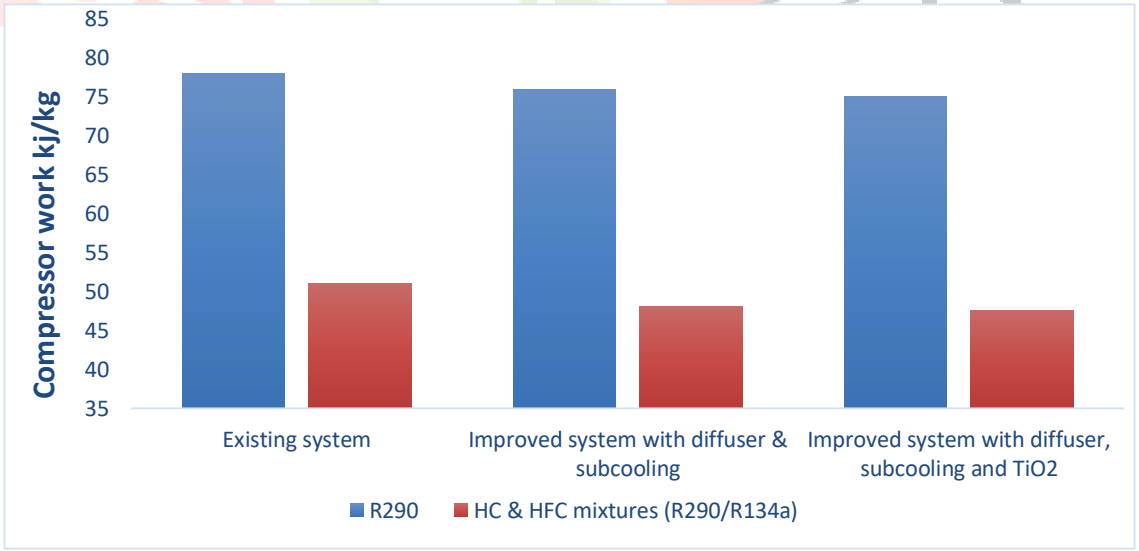
Comparison of Refrigeration Effect



Graph.7.1. Comparison of Net Refrigeration Effect

The above chart shows that the refrigeration effect of both the refrigerant R290 and HC mixture R290/R134a (30g + 50g) for the existing system and the improved system. Refrigeration effect for the existing system using refrigerant R290 is 197.875 kj/kg and the refrigeration effect for the existing system using blended HC & HFC mixtures R290/R134a is 265 kj/kg. Refrigeration effect for the improved system with diffuser & sub-cooling using refrigerant R290 is 203.75 kj/kg and the refrigeration effect for the improved system with diffuser & sub-cooling using blended HC & HFC mixtures R290/R134a is 285 kg/kg. Refrigeration effect for the improved system with diffuser, sub-cooling and TiO2 nano lubricant using refrigerant R290 is 215.75 kj/kg and the refrigeration effect for the improved system with diffuser, sub-cooling and TiO2 nano lubricant using blended HC & HFC mixtures R290/R134a is 295 kj/kg. The refrigeration effect of the modified system with diffuser& sub-cooling is increased due to refrigerant is blended HC & HFC mixtures R290/R134a compared to R290 and further the refrigeration effect is increased due to addition of TiO2 nano lubricant in compressor.

Comparison of Compressor Work

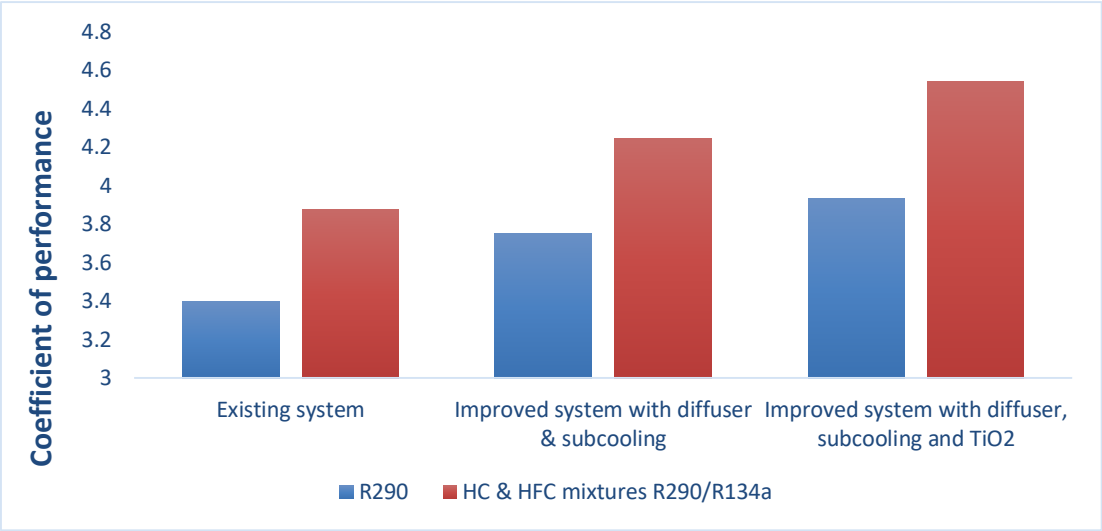


Graph.7.2. Comparison of Work of Compression

The above chart shows that the compressor work of both the refrigerant R290 and blended HC & HFC mixtures R290/R134a (30g + 50g) for the existing system and the improved system. Compressor work for the existing system using refrigerant R290 is 78 kj/kg and the compressor work for the existing system using blended HC & HFC mixtures R290/R134a is 51 kj/kg. Compressor work for the improved system with diffuser & sub-cooling using refrigerant R290 is 76 kj/kg and the compressor work for the improved system with diffuser & sub-cooling using blended HC & HFC mixtures R290/R134a is 48 kg/kg. Compressor work for the improved system with diffuser, sub-cooling and TiO2 nano lubricant using refrigerant R290 is 75 kj/kg and the compressor for the improved system with diffuser, sub-cooling and TiO2 nano lubricant using blended HC & HFC mixtures R290/R134a is 47.5 kj/kg. The compressor

work of the modified system is decreased due to diffuser. In actual case refrigerant leaves the compressor with high velocity which results in splashing of the liquid refrigerant in the condenser. A diffuser is brazed at the inlet of the condenser and is result in the considerable decrease in compressor work.

Comparison of COP



Graph.7.3. Comparison of COP

The above chart shows that the coefficient of performance of both the refrigerant R290 and HC & HFC mixtures R290/R134a (30g + 50g) for the existing system and the improved system. Coefficient of performance for the existing system using refrigerant R290 is 3.2974 and the coefficient of performance for the existing system using HC & HFC mixtures R290/R134a is 3.879. Coefficient of performance for the improved system with diffuser & sub-cooling using refrigerant R290 is 3.75 and the coefficient of performance for the improved system with diffuser & sub-cooling using HC mixture R290/R134a is 4.244.Refrigeration effect for the improved system with diffuser, sub-cooling and TiO2 nano lubricant using refrigerant R290 is 3.9334 and the refrigeration effect for the improved system with diffuser, sub-cooling and TiO2 nano lubricant using HC & HFC mixtures R290/R134a is 4.5421.The coefficient of performance of the modified system with diffuser, sub-cooling and TiO2 nano lubricant is increased due to the refrigerant is HC & HFC mixture R290/R134a when compared to R290. COP of modified system is increased due to reduction in compressor work and increase in refrigeration effect. For reduction in compressor work diffuser is used and sub-cooling is used to increase the refrigeration effect. for the increase in refrigeration effect sub-cooling is used.

VIII. CONCLUSIONS

This paper aims to provide an experimental analysis on performance of domestic refrigerator using HC&HFC blend R290/R134a as refrigerant with TiO_2 nanoparticles.

By comparing both the refrigerants R290 and HC & HFC mixture R290/R134a with modified system with diffuser and sub-cooling it is obserbed and increases of 0.60 in COP.The modified VCR system with the condenser inlet and sub-cooling at condenser outlet.

By comparing both the refrigerants R290 and HC & HFC mixture R290/R134a with modified system with diffuser and sub-cooling it is obserbed and decreases of 0.11 in power consumption.The modified VCR system with the condenser inlet and sub-cooling at condenser outlet.

Hence it is recommended that to replace a diffuser at the condenser inlet and sub-cooling at condenser outlet. These gives an increases in discharge preesure and refrigeration effect, reduces the work done by compressor and power consumption for refrigerator of 165 liters of capacity with R290 and blended mixture R290/134a as refrigerants.

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